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SHORT COMMUNICATION

A beluga whale socialized with bottlenose dolphins imitates their whistles

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Abstract The research on imitation in the animal kingdom has more than a century-long history. A specific kind of imitation, auditory–vocal imitation, is well known in birds, especially among songbirds and parrots, but data for mammals are limited to elephants, marine mammals, and humans. Cetaceans are reported to imitate various signals, including species–specific calls, artificial sounds, and even vocalizations from other species if they share the same habitat. Here we describe the changes in the vocal repertoire of a beluga whale that was housed with a group of bottlenose dolphins. Two months after the beluga's introduction into a new facility, we found that it began to imitate whistles of the dolphins, whereas one type of its own calls seemed to disappear. The case reported here may be considered as an interesting phenomenon of vocal accommodation to new social companions and cross-species socialization in cetaceans.

Keywords Beluga whale *Delphinapterus leucas* · Bottlenose dolphin *Tursiops truncatus* · Vocal imitation · Vocal convergence

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Introduction

The research on imitation in the animal kingdom, as well as debates over the definition of the term "imitation", has more than a century-long history (see reviews by Galef Jr 1988; Whiten and Ham 1992). Although numerous examples of imitative-like behavior have been collected during this time, the cases of true imitation defined as when "a new behavior is learned by copying it from someone else" (Blackmore 1998), are scarce among non-human animals. A specific kind of imitation, auditory–vocal imitation, is well known in birds, especially among songbirds and parrots, but data for mammals are limited to elephants, marine mammals (phocids and cetaceans), and humans (Janik and Slater 1997; Tyack 2008).

One of the important factors that may enhance the vocal imitation ability is vocal plasticity or vocal flexibility (Mercado et al. 2014). Cetaceans are the only mammals besides humans that exhibit the extraordinary capacity for this. They may acquire the species–specific acoustic repertoires through vocal learning (Bowles et al. 1988; Sayigh et al. 1990; Ford 1991; Fripp et al. 2005; Vergara and Barrett-Lennard 2008) and adjust their calls to the acoustic environment (Lesage et al. 1999; Foote et al. 2004; Scheifele et al. 2005). Some toothed whales are reported to imitate untypical signals such as computer-generated sounds (Richards et al. 1984; Reiss and McCowan 1993; Murayama et al. 2014), human speech (Lilly 1965; Ridgway et al. 2012; Murayama et al. 2014), and vocalizations from other species if they share the same habitat (Foote et al. 2006; Musser et al. 2014). Some of these studies (Eaton 1979; Ridgway et al. 2012; Murayama et al. 2014; Musser et al. 2014) indicate that cetaceans, like humans, retain their vocal imitation abilities in adulthood.

The belugas' (*Delphinapterus leucas*) capacity for vocal learning is well documented in captivity: Belugas learn conspecific calls from their relatives (Vergara and Barrett-Lennard 2008) and can spontaneously imitate the sounds that they often hear such as human speech (Ridgway et al. 2012) and some others (see Vergara 2011, p. 8). In a controlled experiment, a beluga was able to imitate computer-generated artificial sounds and correctly reproduce rhythm and intonation of vocal sounds emitted by an experimenter (Murayama et al. 2014).

As common inhabitants of aquariums, belugas and bottlenose dolphins (*Tursiops truncatus*) are often housed together in the same facility where they form unusual "cross-species" communities. Taking into account such factors as high sociality of toothed whales (Connor 2000), an important role of acoustic communication in their life (Tyack and Clark 2000), and the ability for vocal learning (Janik 2014), we expect that the joint keeping of belugas and dolphins in a dolphinarium may change their acoustic behavior, adapting it to new social partners.

Numerous studies conducted both in nature and in captivity have described the vocal repertoires of these two cetacean species quite fully. The most characteristic sounds of bottlenose dolphins are "signature whistles" that are stereotyped repeated whistles with individually unique frequency modulation patterns (Caldwell et al. 1990; Janik and Sayigh 2013). Signature whistles serve to maintain contact between members of a social group and provide individual identification of dolphins (Janik and Slater 1998; Sayigh et al. 1999; Janik et al. 2006), and may encode other, context-related forms of information (Janik et al. 1994). In addition to whistles, bottlenose dolphins produce burst-pulse sounds and echolocation clicks (Caldwell et al. 1990). Belugas possess a rich vocal repertoire that includes a wide variety of tonal, pulsed, noisy, and biphonic pulsed–tonal vocalizations (Sjare and Smith 1986a; Karlsen et al. 2002; Belikov and Bel'kovich 2006, 2007, 2008; Chmelnitsky and Ferguson 2012; Garland et al. 2015), the function of the vast majority of which remains unclear. Field studies have revealed only general correlations between belugas' behavior activity and the acoustic signalization accompanying it (Sjare and Smith 1986b; Karlsen et al. 2002; Belikov and Bel'kovich 2003; Panova et al. 2012). Nevertheless, recent studies conducted in captivity (Vergara and Barrett-Lennard 2008; Vergara et al. 2010; Morisaka et al. 2013; Mishima et al. 2015) have identified contact calls in belugas. These signals are stereotyped broadband pulsed trains or mixed (biphonic) pulsed–tonal calls (Vergara and Barrett-Lennard 2008; Vergara et al. 2010; Mishima et al. 2015; Panova et al. 2017) and, therefore, significantly different in physical structure from signature whistles of bottlenose dolphins. On the whole, the structure of beluga vocalizations seems to be more similar to that of other small whales, such as killer whales (Ford 1989; Thomsen et al. 2001; Riesch et al. 2006), short-finned *Globicephala macrorhynchus* (Sayigh et al. 2013) and long-finned *G. melas* (Nemiroff and Whitehead 2009; Vester et al. 2014) pilot whales.

Here we report a case when a beluga housed together with a group of bottlenose dolphins began to imitate their signature whistles, whereas its own contact calls seemed to disappear. This finding illustrates the fact of vocal accommodation to new social companions in cetaceans as well as their extraordinary vocal plasticity.

Materials and methods

Subjects and facility

This work was a part of the research on the acoustic communication of belugas and bottlenose dolphins that has been conducted by the authors in the Koktebel dolphinarium since 2010. The dolphinarium consists of a big round pool (530 m^2, depth 5 m) connected to a small pool (20 m^2, depth 2.5 m) by a gate (1.5 × 1.5 m). Four bottlenose dolphins are kept here: an adult 30-year-old male D, two 10–11-year-old adult females M and Z, and a young 1.5–2-year-old female MA. The beluga, a young 4-year-old female, was introduced into the Koktebel dolphinarium in November 2013. She came from another facility where she was being housed with other belugas and was also in acoustic contact with bottlenose dolphins kept in an adjacent pool.

Equipment

Audio recordings were made using custom-made hydrophones (P.P. Shirshov Institute of Oceanology, 5 Hz–30 kHz ± 3.0 dB) and Ritmix RR-900 digital recorder (20 Hz–22 kHz ± 6 dB, 44.1 kHz sampling rate). Although the frequency range of the recording system was limited to 22 kHz, the analysis of higher frequency (up to 48 kHz) audio recordings made by the authors before the beluga's introduction revealed no dolphins' whistles with the fundamental frequency above 22 kHz. Judging from the high frequency audio recordings of wild belugas (Panova and Agafonov, unpublished data), the majority of their whistles also does not extend into the ultrasonic range.

Data collection

At first, audio recordings were collected in the main pool when the beluga was first introduced and within 3 days after that (November 2013). Later we had a chance to make recordings during her isolation in the small pool. Two isolation series were conducted: 2 months after the beluga's introduction (first isolation series = 41 isolation sessions,

January–February 2014) and 9 months later (second isolation series = 10 isolation sessions, October–December 2014). The duration of isolation sessions was 20–70 min. Altogether, more than 90 h of audio recordings were obtained. Unfortunately, we did not have the opportunity to isolate the beluga immediately or during the first weeks after her introduction, nor do we have any audio recordings from her previous facility.

The audio recordings were not accompanied by the collection of ethological data; however, we can provide some information about the beluga's and the dolphins' behavior. The first appearance of the beluga in the dolphinarium caused a fright in the dolphins. Soon the situation stabilized, and during this study, the relationships between the animals were neutral or friendly. In August 2016, one of the female dolphins gave birth to a male calf, and after a while he was regularly observed swimming with the beluga.

Identification of beluga's vocalizations

Since the authors documented the vocal repertoire of the bottlenose dolphins before the beluga's introduction (Agafonov and Panova 2012; Agafonov and Panova, unpublished data), her signals were initially identified as novel types of signals that had not been previously recorded. In the audio recording, these new signals often overlapped with signature whistles of the bottlenose dolphins, suggesting that they belonged to the beluga. Later, for unequivocal identification of sounds produced by the beluga, she was temporarily isolated in the small pool. Each pool was equipped with a hydrophone (Fig. 1), so we had the opportunity to distinguish the sounds produced in the different pools by applying two-channel recordings. As the call that originated from one of the pools was significantly attenuated compared to a call from the other, we could localize its source (dolphins vs. beluga) by comparing the sound amplitude in the two recording channels.

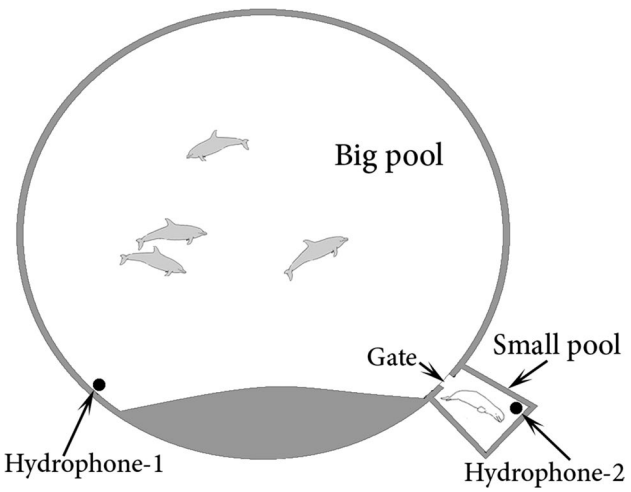

Fig. 1 A schematic view of the Koktebel dolphinarium. Locations of the gate and the hydrophones are shown

Analysis of audio recordings

All the recordings were examined through a visual inspection of spectrograms (FFT size: 512, window type: Blackman, a 5-s viewing window with the frequency range up to 22 kHz) in Adobe Audition 3.0 (© 1992–2007 Abode Systems Inc.) For further analysis, we selected a 20-min-long fragment of the audio recording when the beluga was first introduced (during that time she was very vocal, after that her vocal activity dramatically dropped), 10 isolation sessions from the first isolation series (the first 20 min of each session totaling 200 min), and 6 isolation sessions from the second isolation series (the first 17–20 min of each session totaling 117 min).

To identify the imitation events, we followed the methodology of the studies of whistle matching in bottlenose dolphins (Janik 2000; King et al. 2013). Initially, one of the authors (E.P.) selected the beluga's whistles that resembled those of the dolphins. The cases when there were doubts about the source of a whistle were excluded. Then, three human observers, who had prior experience in the classification of cetacean vocalizations but were not involved in the current study, were asked to score the similarity of each supposed imitation to the original whistle. The similarity was estimated on a scale of 1 (dissimilar) to 5 (similar, but not necessarily identical). The analysis of the agreement between the observers showed statistically significant similarity of their scores (Kendall's coefficient of concordance $W = 0.58$, $p < 0.001$). The beluga's whistles with an average score of 3 or more were counted as imitations. To determine whether the accuracy of imitation increased over time, we compared the scores of the imitations from the first and the second isolation series using Mann–Whitney U test.

The rest of the beluga's vocalizations were grouped into broad categories such as whistles (narrow-band tonal sounds), pulsed calls, biphonic pulsed–tonal calls (for more information about the vocal repertoire of belugas and the classification of their calls, see Sjare and Smith 1986a; Karlsen et al. 2002; Belikov and Bel'kovich 2006, 2007, 2008; Chmelnitsky and Ferguson 2012; Garland et al. 2015).

Although it was beyond the scope of this study, we also searched for any cases of imitation of the beluga's calls by the dolphins.

Results

Just after the introduction, the beluga started to produce calls typical for her species (Table 1; Fig. 2a, *1–3*): short

Table 1 Main categories of signals produced by the beluga during its introduction into the dolphinarium and isolation sessions

Call types	Introduction (20 min), November 2013	First isolation series (10 isolation sessions totaling 200 min), January–February 2014	Second isolation series (6 isolation sessions totaling 117 min), October–December 2014
Short whistles ("squeaks"), *n*	36 (27.5%)	315 (44.3%)	857 (51.8%)
Short pulsed vowel-like sounds ("vowels"), *n*	14 (10.7%)	93 (13.1%)	83 (5.0%)
Combination "squeak + vowel", *n*	76 (58.0%)	40 (5.6%)	19 (1.1%)
Biphonic pulsed–tonal contact calls, *n*	5 (3.8%)	0 (0%)	0 (0%)
Other whistles, *n*	0 (0%)	50 (7.0%)	354 (21.4%)
Other pulsed sounds, *n*	0 (0%)	162 (22.8%)	212 (12.8%)
Imitations of signature whistles, *n*			
Total	0 (0%)	35 (4.9%):	19 (1.1%)
Specified by dolphins: dolphin Z (adult female)	–	31 (score = 3.96)	12 (score = 3.64)
Dolphin M (adult female)	–	4 (score = 3.58)	5 (score = 3.53)
Dolphin D (adult male)	–	0	2 (score = 3.83)
Imitations of shared whistles, *n*	0 (0%)	16 (2.2%) (score = 4.15)	112 (6.8%) (score = 4.31)
Total signals, *n*	131 (100%)	711 (100%)	1656 (100%)

For imitations, the average scores are indicated in parentheses

whistles ("squeaks") and pulsed vowel-like sounds ("vowels") (see types W1 and lPT1 in Belikov and Bel'kovich 2007, 2008), that could be emitted simultaneously, as well as biphonic pulsed–tonal calls, which seemed to be her contact calls (see Vergara et al. 2010). Later, other whistles and pulsed signals were also detected (Fig. 2a, *4–5*).

The analysis of the audio recordings collected during the isolation sessions revealed that although short whistles and pulsed vowel-like sounds were still predominant types in the beluga's vocalizations, biphonic pulsed–tonal contact calls were no longer recorded (Table 1). Instead, the beluga's vocal repertoire was supplemented with new signals resembling whistles made by the dolphins. Thus, we found imitations of signature whistles belonging to the three adult dolphins (the imitations of the female Z whistles were most common), as well as whistles shared by all of the dolphins (Fig. 2b–e; Table 1). Imitations of signature whistles comprised 4.9% of the beluga's vocalizations during the first isolation series, and only 1.1% during the second series; the imitations of the shared whistle comprised 2.2 and 6.8% of her vocalizations respectively.

The comparison of the imitation scores revealed no statistically significant differences between the first and the second isolation series ($U = 763.5$, $p = 0.34$ for imitations of shared whistles; $U = 121.5$, $p = 0.08$ for imitations of the dolphin Z signature whistles; other imitations were not analyzed because of the small sample size).

Among the dolphins' vocalizations, we found a case of production of short calls that were similar to the beluga's "squeak + vowel" combinations (Fig. 2f).

Discussion

A 50-year study of the acoustic communication of dolphins and whales has left no doubt that these animals are good vocal learners (Janik 2014). So, the fact of the imitation of dolphins' whistles by a beluga does not seem surprising. The absence of differences in imitation accuracy between the first (2 months after the beluga's introduction) and the second (11 months after the introduction) isolation sessions suggests that the acquisition of dolphin whistles by the beluga took no more than 2 months. However, the lack of audio recordings made in the first days after the introduction is one of the disappointing limitations of this work, because it was experimentally shown that an adult beluga was able to correctly imitate a novel sound at its first presentation (Murayama et al. 2014).

In addition to the appearance of new signals, another interesting change in the vocal repertoire of the beluga was noted, namely the disappearance of her own contact calls. It can be supposed that these signals, which are needed for individual (or group) recognition and group cohesion (Vergara et al. 2010; Morisaka et al. 2013), became unnecessary without conspecifics. On the other hand, the results of Vergara et al. (2010) and Mishima et al. (2015) demonstrated that the proportion of contact calls in beluga's vocalizations can vary widely—from more than 90% during birth and death of a calf (Vergara et al. 2010) to the total absence in some isolation sessions (Mishima et al. 2015). In this respect, the behavior of belugas strongly contrasts with that of bottlenose dolphins, which persistently produce

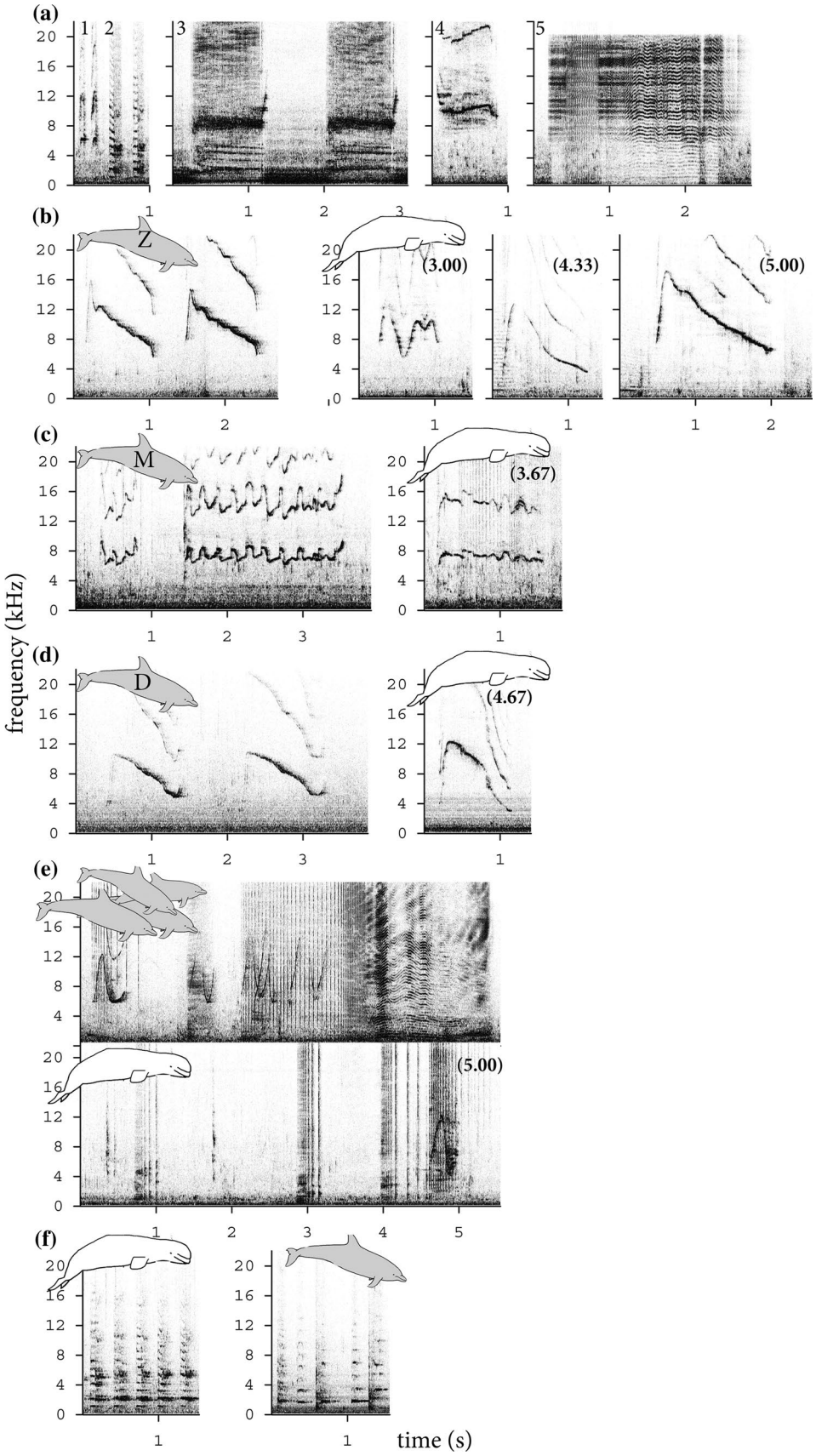

Fig. 2 Spectrograms of acoustic signals produced by the beluga and the bottlenose dolphins (visualized with sound analysis software Syrinx 2.6 h): **a** the beluga's species–specific vocalizations: short whistles (1), combinations of short whistles and pulsed vowel-like sounds (2), biphonic pulsed–tonal calls (3), whistle (4), and pulsed call (5); **b**–**d** signature whistles produced by the individual bottlenose dolphins Z, M, and D (left) and their imitation by the beluga (right); **e** two-channel audio recording that illustrates the simultaneous production of shared whistles by the bottlenose dolphins (upper) and their imitation by the beluga (bottom); **f** combinations of short whistles and pulsed vowel-like sounds produced by the beluga (left) and their presumed imitation by the dolphins (right). The score for each example of beluga's imitation is indicated in parentheses. The sound files are available as electronic supplementary material

signature whistles in isolation (Janik et al. 1994; Janik and Slater 1998; Agafonov and Panova 2012). Thus, one cannot exclude an assumption that the isolation procedure used in our study (by which the acoustic and, partly, the visual contact between the animals were maintained) was not a sufficient condition for producing contact calls by the beluga.

The inspection of the audio recordings made before and after the beluga's introduction revealed that the cross-species imitation was not reciprocal: While the imitations of dolphin whistles were regularly detected among the beluga's vocalizations, we found only one case, in which the dolphins produced short calls that resembled (but were not identical in physical parameters) those of the beluga. Although such calls were not observed in the dolphins' vocal repertoires during our previous acoustic study (Agafonov and Panova 2012; Agafonov and Panova, unpublished data), the lack of prominent acoustic features (such as frequency modulated contour in signature whistles, for example) in these simple, short calls prevented a human observer from making a decision on whether this case was an imitation or not.

At the same time, it is a well known fact that imitation ("mimicry") of signature whistles occurs in groups of bottlenose dolphins (Tyack 1986; Agafonov and Panova 2012; King et al. 2013; King et al. 2014), especially among individuals that form long-term social bonds, such as mother–calf pairs or male alliances (King et al. 2013). According to various studies, the proportion of imitated whistles in the vocalizations of different individuals varies from less than 1% up to 19–21% (Tyack 1986; Janik and Slater 1998; Agafonov and Panova 2012). In addition, it has been reported that allied males may share their whistle repertoires (Watwood et al. 2004). The role of whistle copying in the dolphin communication remains unclear. It is thought to be affiliative and may serve to address the specific individual associated with that whistle (King et al. 2014).

In this study, the differences in imitation behavior between the beluga and the dolphins can be explained by the different social conditions facing these individuals. Highly social in nature (Krasnova et al. 2009, 2014; Chernetsky et al. 2011; Colbeck et al. 2013), this beluga was the only representative of her species in the facility. Probably, the absence of conspecifics motivated the beluga to integrate into an allospecific social group, adapting her acoustic signalization to the new social partners.

The case reported here, as well as other instances of imitation and whistle sharing in dolphins described in the literature, may be considered as vocal convergence between socially bonded individuals—a phenomenon that can be seen in various vocal species, from birds to humans (Tyack 2008). With some exceptions, call convergence is suggested to provide recognition of a group and strengthening of social bonds between its members (see review in Tyack 2008). However, in contrast to this "communication-focused hypothesis", there is an alternative "ranging hypothesis", according to which the ability of cetaceans (as well as birds) to imitate sounds is necessary for a successful localization of sound sources, and for monitoring and prediction of the actions of conspecifics (Mercado et al. 2014). This is especially important for cetaceans, which live in a visually restricted environment (Mercado et al. 2014).

The lack of ethological observations in the current study does not allow us to draw any conclusions about how the beluga uses imitations and why she imitates. However, this phenomenon is of great interest to understand the mechanisms of interspecies communication.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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